Appendix F: Data Preparation[1]

The baseline scenario includes the following assumptions: growth in traffic, changes in fleet mix, and continuous support of improvement of airports and procedures. The enhanced CNS/ATM scenario includes the assumptions for the baseline scenario and the addition of new technologies. Data preparation for these scenarios included the process for building future flights and the assignment of aircraft type and trajectories. The following paragraphs describe the process in detail.

Developing Future Flight Data

To build an extension to the baseline scenario, two sets of flight data were generated for each of the future years (1996, 2005, 2010, and 2015). The first set consisted of flight data for all scheduled commercial flights. The second set consisted of all general aviation and military flights.

The initial base year was constructed using the scheduled or commercial flights from the OAG for November 12, 1996. The origin airport, destination airport, scheduled times, flight identifier, and aircraft type were obtained for each scheduled flight in the NAS.

Along with the scheduled flights, the general aviation and military flights were obtained from the November 12, 1996, ETMS data. Flights were identified as general aviation or military based upon their flight identifiers. A set of flight data was obtained for these flights consisting of the origin airports, destination airports, actual times of flight, and aircraft type.

The scheduled flights and the general aviation and military flights combined to capture the majority of the activities in the NAS. The next step was to grow the traffic to reflect the projected demand as described in the TAF.

The above data sets were input into the FDG to increase the traffic demand to the levels expected for 2005, 2010, and 2015. The FDG provided the future flights. Once the new flights were obtained for each scenario, the aircraft types were modified in each year to account for fleet modernization and acquisition of new aircraft. Trajectories were then assigned to each flight, first in the baseline scenario and subsequently in the enhanced scenario, which were optimized for the future concept of operations.

Assignment of Aircraft Types

To assign an aircraft type to a new flight, a database of fleet mix for the specific future year was used. For each future year, the fleet mix, consisting of the number of each aircraft type (e.g., B737) anticipated to be in service by that year), was obtained. This forecast was used to assign an aircraft model to each flight in the future. The following assumptions were included:

[1] This appendix was developed by Stephane Mondoloni (CSSI, Inc.) and Diana Liang (FAA/ASD-400).

- New aircraft are added to the list by assuming that they would fly the same distribution of stage lengths as an aircraft in the same category.

- New aircraft would fly the same number of legs per aircraft per day as similar aircraft.

An important factor in the assignment of aircraft type to a new flight is stage length. The number of legs flown by each aircraft per day is a function of stage length. A process was derived to assign the aircraft type to each flight based on the travel distance of each flight. (See Figure F-1 below.)

Figure F-1. Assignment Aircraft Type by Stage Length and Fleet Mix Projections

Baseline: Number of flights by stage length.

Type	Stage Length (nmi)				Total
	0 - 250	250 – 500	500– 750	…	
B737					
A300					
Total					

Multiply by growth to types

Future: Number of flights by stage length.

Type	Stage Length (nmi)				Total
	0 - 250	250 – 500	500– 750	…	
B737					
A300					
Total					

Obtain percentages by column

Future: Fraction of flights by stage length.

Type	Stage Length (nmi)			
	0 - 250	250– 500	500– 750	…
B737				
A300				
Total	100%	100%	100%	100%

The FDG assigned the jet or turboprop category to a future flight. This information was used to assist in the assignment of fleet mix to the new individual flights. A flight that was a jet or turboprop in 1996 remained so in the future years.

The 1996 OAG data was used to build a matrix that contained the number of flights by aircraft type and stage length. The projected growth in the number of aircraft of a given type was used to grow the number of flights by stage length for that aircraft type. Thus, it was assumed that aircraft of a given type would continue to operate on flights with the same distribution of stage length. Finally, the fraction of flights of a given stage length using each aircraft type was obtained. These were used to assign the aircraft type by stage length for all the flights in the future years.

As an example, if there were 120 flights with a stage length of 250-500 nautical miles (nmi) of jet aircraft X in 1996, and aircraft X was to grow 20% by 2010, there would be 144 flights of aircraft X in 2010 with a stage length of 250-500 nmi. If the total number of jet flights with a stage length of 250-500 nmi was 1000 in 1996 and 1300 in 2010, the probability of a jet flight with a stage length of 250-500 nmi being assigned aircraft X would be 11% (144/1300).

Assignment of Tracks

Once the flight origin and destination were identified and the aircraft type was assigned to the flight, a track was assigned. A track consists of a series of points between the flight's origin and its destination. The assignment is done randomly by selecting a track from the set of all filed tracks for the same origin and destination. The set of all filed tracks between city pairs was obtained through the ETMS data set. For example, if a flight flew from ORD to LAX, one track was selected from all filed tracks between ORD and LAX. Once the track was assigned, the altitude and speed trajectory was assigned to that track to establish a flight trajectory.

Assignment of Trajectories – Baseline Scenario

For the baseline scenario, speed and altitude profiles were assigned to each flight as a function of the track, aircraft type, desired cruise altitude, and airspeed en route. For each aircraft type, a climb profile was defined by a sequence of altitudes and airspeeds. When detailed aircraft information was available, it represented the fastest allowable climb to altitude as a function of stage length. The stage length was used to identify the aircraft weight. Aircraft going further are heavier and cannot climb as fast. In general the climb trajectory represented the average climb rates actually flown by analysis of ETMS data for that aircraft type. In today's operation, the aircraft climb and descend in steps. An aircraft climbs to an assigned altitude and plateaus for a time before climbing to the next assigned altitude. In this study, plateaus were removed from climb trajectories.

Once flights reached their cruise level (speed and altitude), the flights continued to fly along the track at the specified airspeed and altitude. The time at points along the track was computed by translating the airspeed to ground speed using the wind velocity field for November 12, 1996.

The descent trajectory was imposed on each flight as a function of the year being analyzed, then as a function of the aircraft type. For 1996 and 2005, the descent trajectory that was used corresponded to procedural descents obtained by looking at the descent trajectory of flights under current operations (summarized in Table F-1). For aircraft whose speed during descent was significantly below that specified in the table, the speed during descent was obtained from that observed in actual descents for that aircraft. The trajectory (distance versus altitude) was maintained as specified in Table F-1.

Table F-1. Description of Procedural Descent Trajectory

Altitude	Distance From Airport.	Speed (kts)	Descent Rate (fpm)
25,000	125	445	1000
20,000	90	400	1670
15,000	70	400	1250
10,000	50	250	830

For the years beyond 2005, the descent trajectory was obtained by averaging the descents obtained in ETMS data by aircraft type after altitude plateaus were removed. This provided a descent in which aircraft were allowed to descend uninterrupted.

The general aviation, or unscheduled aircraft, trajectories were assigned based on their actual trajectories as reported in the ETMS messages. These messages represent the position updates (at 5-minute increments) for all controlled flights in the NAS. This could be done for the 1996 baseline data since GA and military flights were obtained from the ETMS data. Thus, there was a one-to-one correspondence between the GA/military demand data and the ETMS data set. The trajectories of new GA/military flights, added by the FDG, were obtained by copying the trajectory of an existing flight between the origin and destination for that same equipment category. Note that no projection for fleet mix of general aviation or military aircraft was attempted.

Assignment of Trajectories – Enhanced Scenario

Optimized trajectories were developed for the enhanced scenario beginning with the baseline trajectories for each year using the OPGEN portion of the NARIM suite of tools. Trajectories were optimized only for the portion of the flight above 24,000 feet in 1996 and 2005. Beyond 2005, the portion of the flight above 15,000 feet was optimized for distance or fuel. Thus, the climb and descents to and from 24,000 feet and 15,000 feet were held constant in 1996-2005 and 2010-2015, respectively.

Flights that flew less than 1,000 nmi in the baseline were not optimized for minimum fuel, but had their distances reduced as much as possible so that active special use airspace (SUA) was still avoided. For these flights, the direction around SUA was held constant. (If the aircraft went left of SUA, it continued to go left around the SUA.) Only the portion of the flight above the cutoff altitude described in the preceding paragraph was modified. For flights that did not climb above the cutoff altitude, the flight trajectory was not modified. As the distance of the flights reduced, the flight speed was assumed to remain constant between the two scenarios, thus the times at each waypoint were modified to reflect the shorter flight paths. The arrival time was preserved between the baselines and the modified scenarios. The arrival time was preserved since this is what airlines prefer. If the airlines knew they could leave later (and possibly fill more seats) and still arrive on time they would rather do that than get to the destination early.

Flights that flew more than 1,000 nmi in the baseline, for which we had no aircraft performance data, were assumed to fly the minimum distance as above.

The remaining flights that flew more than 1,000 nmi in the baseline were modified above the cutoff altitude so that they would consume a minimum amount of fuel while still meeting the same time en route. If the flight could fly faster and reduce the consumed fuel further, it was assumed to do so. If the flight could not meet the desired time due to constraints, it was assumed to fly in a minimum time. Certain constraints were imposed on the allowable trajectories. These constraints are summarized below.

- Aircraft performance constraints (maximum thrust, maximum speed, etc.).

- Avoidance of active SUA.

Flights must cruise at valid altitudes for direction of flight. In 1996, current valid cruising altitudes for direction of flight were assumed. For 2005 and 2010, Reduced Vertical Separation Minima (RVSM) rules of flight were imposed. In the 2015 scenario, no altitude limits were imposed, since it was assumed that flights were allowed to cruise climb.